IEEE PES Distinguished Lecturer Seminar

DC Transmission Grids

Topology, Components, Modelling, Control and Protection Challenges

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University of Washington
ECE 303
185 W Stevens Wy NE,
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High Voltage DC Transmission has seen rapid technology advances in the last 20 years driven by the implementation of VSC (Voltage Source Converters) at GW powers and in particular introduction of MMC (Modular Multilevel Converters). The development of interconnected DC transmission grids requires significant further advance from the existing point-to-point HVDC links. It is widely believed that complex DC power grids can be built with comparable performance, reliability, flexibility and losses as traditional AC grids. The primary motivation for DC grid development is the need for power flow and trading between many DC terminals, as an example in the proposed (350 GW) North Sea DC grid, or EU-wide overlay DC grid. AC transmission is not feasible with long subsea cables, and it is inferior to DC systems in many other conditions. This presentation addresses the options and challenges with DC grid development, referring also to state-of-art technology status.

Zhangbei 4-terminal DC system (China, 2020) represents the first implemented GW-scale meshed DC transmission grid, which employs bipolar ring topology with overhead lines and 16 DC Circuit Breakers. However, multiple studies illustrate advantages of some radial, hub-based or segmented topologies, because of component costs, and challenges with interoperability, ownership, DC markets, operation, security and reliability.

MMC concepts, including half-bridge and full-bridge modules, will underpin DC grid converters and further advances like hybrid LCC/MMC converters have been implemented recently. DC/DC converters at hundreds of MW are not yet commercially available but there is lot of research world-wide, and some lower-power prototypes have been demonstrated. DC/DC converters may take multiple functions including DC voltage stepping (transformer role), DC fault interruption (DC CB role) and power flow control. Multiport DC hubs can be viewed as electronic DC substations, capable of interconnecting multiple DC lines.

Very fast DC CB circuit breakers (2 ms) have become commercially available recently, but the cost is considerably higher than AC CBs. Slightly slower mechanical DC CBs (5-8 ms) are also available from multiple vendors, while new technical solutions are emerging worldwide for achieving faster operation with lower size/weight/costs.

DC grid modelling will face the new challenge of numerous converters dynamically coupled through low-impedance DC cables/lines. A compromise between simulation speed and accuracy is required, leading to some average-value modelling, commonly in rotating DQ frame, but capturing very fast dynamics and variable structure to represent fault conditions.

The principles of control of DC grids have been developed. DC systems have no system-wide common frequency to indicate power unbalance, and voltage responds to local and global loading rather than reactive power flow. DC grid dynamics are 2 orders of magnitude faster than traditional AC systems and most components will be controllable implying numerous, fast control loop interactions. Because of lack of inertia, and minimal overload capability for semiconductors, DC grid primary and secondary control should be feedback-based (man-made), fast, and distributed. International standardization efforts have begun.

The protection of DC grids is a significant technical challenge, both in terms of components and protection logic. The selectivity has been demonstrated within 0.5 ms timeframe using commercial and open-source DC relays. Nevertheless, grid operators have expressed concerns with self-protection on various components, back-up grid-wide protection, interoperability, and in general if we can achieve power transfer security levels comparable with AC grids and acceptable to stakeholders.

Speaker – Professor Dragan Jovcic, FIEEE
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Dragan Jovcic obtained a Diploma Engineer degree in Control Engineering from the University of Belgrade, Serbia in 1993 and a Ph.D. degree in Electrical Engineering from the University of Auckland, New Zealand in 1999. Since 2000 he has been an academic in UK, and since 2012 a chaired professor with University of Aberdeen. In 2008 he held a visiting professor post at McGill University, Canada. Prof Jovcic is fellow of IEEE, fellow of IET, and IEEE PES Distinguished Lecturer. He is editor of IEEE Transactions on Power Delivery and IEEE Access.

Professor Jovcic is a member of CIGRE, has been chairman of B4.76 and member of 5 other working groups (B4.52, B4.58, B4.64, B4.80, B4.84). He is founder and director of Aberdeen HVDC research centre where he has managed significant volume of externally funded research projects. Prof Jovcic has around 160 publications and he is author of a book on HVDC: “High Voltage Direct Current Transmission: Converters, Systems and DC Grids”, Wiley, 2015.

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